

**UNDERSTANDING  
THE NATIONAL ENERGY DILEMMA**



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# UNDERSTANDING THE “NATIONAL ENERGY DILEMMA”

A Report of the  
JOINT COMMITTEE ON ATOMIC ENERGY

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**CONTENTS**

	<i>Page</i>
FOREWORD . . . . .	vi
MEMORANDUM OF CHAIRMAN . . . . .	vii
I. Introduction . . . . .	1
II. Summary . . . . .	1
III. Description of "Energy Display" . . . . .	2
IV. Description of Energy "Option-Exercise" Techniques . . . . .	15
V. Conclusion . . . . .	23
APPENDIX . . . . .	24
References . . . . .	24
Conversion tables . . . . .	24

***Fold-outs:***

A. Total Energy Flow Pattern (1950) . . . . .	A
B. Total Energy Flow Pattern (1960) . . . . .	B
C. Total Energy Flow Pattern (1970) . . . . .	C
D. Total Energy Flow Pattern (1980) . . . . .	D
E. Total Energy Flow Pattern (1990) . . . . .	E
F. Sketch Describing "Cross Plot" Construction . . . . .	F
G. Cross Plot of "Efficiency" . . . . .	G
H. Cross Plot of "End Uses" . . . . .	H
I. Cross Plot of "Form of Use" . . . . .	I
J. Cross Plot of "Supply/Demand" . . . . .	J
K. "S/D Chart"—(From "Energy Display") . . . . .	K
L. "S/D Chart"—(1960 through 1985) . . . . .	L
M. Chart of "Guidance" Required . . . . .	M
N. Chart of Various "Demand" Projections . . . . .	N
O. Chart of "Option Exercise 7-A" . . . . .	O
P. "S/D Chart"—(1900 through 2050) . . . . .	P

## Foreword

Although the emerging energy crisis has already been discussed extensively, the complexity of the issues has made its dimension, scope, and significance to the national economy difficult for the non-expert to comprehend. One of the important deficiencies with respect to public communication has been the lack of an effective device or technique to bring together and to show the interaction of the many energy supply and demand factors in a readily comprehensible manner.

The Center for Strategic and International Studies has kept abreast of the views of the Congress and the international community on this issue. After careful consideration of the problem, the Center has concluded that at least part of this deficiency can be overcome through the use of a unique, three-dimensional, conceptual model. This model is capable of displaying present and projected demand and supply of the various forms and uses of energy as well as efficiencies in energy consumption. The model was developed by the Joint Committee on Atomic Energy and its use is explained in the following Committee material.

CSIS has a long and varied professional interest in the global aspects of the energy dilemma. Its 1968-69 analysis of the implications of British withdrawal from the Persian Gulf highlighted that area's importance in world energy supply. The report was one of the first of its kind published in America. CSIS has subsequently sponsored a number of seminars throughout the United States dealing with developments in the Gulf and other key geo-strategic factors affecting the international supply and demand for energy.

The continuing interest of CSIS in this field is reflected in the fact that three of the first ten studies in the new CSIS series of *Washington Papers* deal with the strategic role of oil, i.e., No. 1, *The Persian Gulf* (1972), R. M. Burrell; No. 4, *Oil, the Middle East and the World* (1972), Charles Issawi; No. 7, *Politics, Oil and the Western Mediterranean* (1973), R. M. Burrell and Alvin J. Cottrell.

It is for the purpose of supplementing and expanding its own continuing work on energy that CSIS has requested and received permission from the Joint Committee on Atomic Energy to reproduce in quantity copies of the Committee model and its explanatory report. The object of CSIS in doing this is to help broaden public understanding of the potential quantitative aspects of the energy dilemma.

It should be emphasized that the energy charts and displays that follow do not, of course, represent actual proposals from the Joint Committee on Atomic Energy or CSIS. They are intended primarily to convey to the reader some notion of the complexity and magnitude of the energy problems facing the United States.

The following report, representing the work of the Joint Committee on Atomic Energy and in particular the Committee's staff, is a welcome addition to the field of energy research. It is, therefore, with great pleasure that we at CSIS undertake the further dissemination and application of this report and the accompanying model in the interest of a better understanding of the problems ahead. It is hoped that this commitment by CSIS will stimulate further research and discussion.

DAVID M. ABSHIRE, *Chairman,*  
*The Center for Strategic and International Studies*

September 1, 1973

## To: Members of the Joint Committee on Atomic Energy

The Joint Committee on Atomic Energy has long considered it essential to have a capability to assess continually the overall national and world energy picture. The Atomic Energy Act provides the AEC with the statutory authority, and the Joint Committee with the Congressional "watch-dog" responsibility, for the conduct of research and development in both civilian nuclear power and non-nuclear energy. The Joint Committee, therefore, must have general information on all energy matters in order to evaluate properly research priorities and other aspects of the Commission's civilian nuclear and non-nuclear energy programs.

Several months ago I requested that the JCAE staff consolidate current energy related data and develop an "Energy Display" system which, in less than an hour, could give an extremely busy person an understanding of the size and the complexity of our national energy dilemma. An additional objective was to develop a display system that would permit the Members to see the potential results of various research and development programs. Utilizing this system, a Member could also evaluate with appropriate perspective the merits of proposed "solutions" to our energy dilemma that are continually being submitted to the Congress.

This Joint Committee print is a revision of an earlier one issued on May 4, 1973, entitled "Certain Background Information for Consideration When Evaluating the 'National Energy Dilemma'." Both prints describe the energy display system developed and give complete instructions for its use.

As in the earlier print, one of the "options" or "exercises" is developed to illustrate how the display system can be used. It does not represent a specific prediction or proposal of the Committee or of the staff, and the described "option-exercise" in *no way* constitutes recommendations. It is described to enable the reader to understand completely the utilization of the suggested systems.

Several comments that we have received concerning the initial print of May 4, 1973, suggested that it would be helpful if we would provide a general display of our overall national energy "supply/demand" over a longer period of time. This enables a reader to gain a better understanding of where the United States stands with reference to the "era" of relatively cheap and available domestic fossil fuels and the next "era"—one requiring an ever increasing supply of non-fossil energy sources and imported energy sources. I, therefore, requested that our staff prepare the last chart in this booklet. In addition, certain technical changes were made to the charts and text. Otherwise, a reader with access to both the original print and this revised version will find the material quite similar.

You will notice that I have requested that the material be presented in a "narrative" form. It is designed to serve as a general reference document for those interested in energy matters. While this print has been prepared primarily for the use of the Joint Committee on Atomic Energy, I welcome its broad discussion and use by the Congress, the Administration, and the public as a whole.

MELVIN PRICE, *Chairman,*  
*Joint Committee on Atomic Energy*

August 15, 1973

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## UNDERSTANDING THE "NATIONAL ENERGY DILEMMA"

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### I. INTRODUCTION

The United States with about 6% of the world's population is now consuming over 35% of the planet's total energy and mineral production. The average American uses as much energy in just a few days as half of the world's people on an individual basis consume in one year. This Nation has literally been developed without any significant restrictions due to lack of energy or mineral resources. However, we now see ever-increasing indications of the fact that the United States cannot long maintain the growth rate of recent years in our energy consumption without major changes in our energy supply patterns.

The complexity of the energy problem has made it imperative that concise communication systems be developed so key people in the government can rapidly grasp the various aspects of this energy dilemma. One excellent communication technique is a visual display to enable decision-makers to see the complexity of our present energy dilemma and the impact of various options that the United States has for dealing with its energy problems. This Joint Committee print describes such a device and system and shows how it can be used to display graphically the subject material.

### II. SUMMARY

The staff of the Joint Committee on Atomic Energy has developed a graphic presentation which enables a person (who is not necessarily an energy specialist) to obtain a reasonable understanding of the broad problems, scale and complexity of our energy dilemma in about an hour. In addition, a method has been devised for visually displaying projected future effects of various energy policies on our domestic energy situation.

### III. DESCRIPTION OF "ENERGY DISPLAY"

The staff has developed an "Energy Display" system that is made up primarily of transparent plexiglass sheets, one series of which has the total energy flow pattern for certain years displayed to scale and another series of sheets, installed at right angles, showing "cross plots" of certain information as each item evolves through the years. This particular device contains no information that has not been available to the public but is unique in its method of presentation. The data displayed are based on the history of the years of 1950, 1960, and 1970, and projections for 1980 and 1990, most of which has been published by the Lawrence Livermore Laboratory based primarily on information released by the Department of the Interior and the National Petroleum Council.<sup>1</sup>

The best way to understand the device described in this committee print is for the reader to open the designated "Fold-out" (when suggested) and then follow its description in the text. The various Fold-outs are located in the rear of this publication.

The energy "unit" used in the display system is that of a million barrels per day of oil equivalent. The reader must fully understand the conversion of all energy values to Barrels Per Day of Oil Equivalent (B/DOE). We chose to use the scale of barrels of oil equivalent<sup>2</sup> to try to make the situation more understandable to the layman, and also because imported oil, usually measured in barrels, is rapidly becoming a major factor in our national energy dilemma. We make these conversions by calculating the energy that would be produced from the various energy forms and then converting those numbers into the number of barrels of crude oil that would have to be used in order to obtain the same amount of energy. For instance, we have taken the tons of coal burned for a particular use and calculated the barrels of oil that would have to be burned in order to obtain the same amount of heat.

In order to give the reader a better concept of the magnitude of the "units" the following table lists several well known items and converts their productive or hauling capacity to oil equivalents.

<sup>1</sup>See Appendix: Ref. 1 and Ref. 2.

<sup>2</sup>See Appendix: Conversion Tables.

### Typical "Oil Equivalents"

Location	Energy form	(Million) B/DOE
Total: State of Texas . . . . .	Oil production . . . . .	3.5 and declining (end 1972).
Total: State of Louisiana . . . . .	Gas production . . . . .	4.2 (end 1972).
Total: State of California . . . . .	Oil production . . . . .	0.9 and declining (end 1972).
Total: State of Pennsylvania . . . . .	Coal production . . . . .	0.9 (end 1972).
Total: State of West Virginia . . . . .	Coal production . . . . .	1.4 (end 1972).
Hoover Dam . . . . .	Electric capacity . . . . .	0.02.
Total U.S. nuclear power . . . . .	Generate Electricity . . . . .	0.3 (end 1972).
Large supertanker . . . . .	Oil per Load . . . . .	1.5 (per voyage).
Alaska Pipe Line (Valdez) . . . . .	Oil Transportation . . . . .	1.5 (projected).
Total U.S. demand . . . . .	All . . . . .	36.0 (early 1973).

It is also important for the reader to become familiar with an energy flow pattern for the United States during a period when the system was relatively simple. Though the pattern for 1950 would be good for this purpose, the proportional factors involved are too small to be rendered to scale with complete legibility in this study. Therefore, the total energy flow pattern for the year 1960 will be used instead as the basic example.

#### Total Energy Flow Pattern (1960)

Open *Fold-out "B."* This is a chart of our national energy flow pattern as it actually existed in the year 1960. All the information shown has been reduced to the same scale and converted to the same "unit" described above. The "unit" (Million B/DOE) is shown in parenthesis after each particular item being described to assist the reader in identifying the exact portion of the chart the reader should be following.

#### Oil (1960)

Start by observing the lower left-hand corner of the chart. Observe that the total U.S. oil supply (9.7) in 1960 consisted of oil from domestic sources (7.8) and oil from imports (1.9). Then ignoring, for convenience sake, the various flow patterns through petroleum refineries and other conversion processes, notice the small amount of oil (0.3) shown to have been used in the generation of electrical energy. Next, note how the U.S. exported some oil (0.2) in the form of petroleum products; utilized a considerable amount (2.0) in the "residential & commercial" end use (about 75% single dwelling and the remainder apartment houses, offices, shopping centers, etc.); considerably less (1.3) in "industry" (iron and steel, auto manufacturing, etc.); even less in "non-energy" (0.8) uses (manufacture of fertilizers, plastics, paints, etc.), and used the largest share of our oil (5.0) in the "transportation" sector (autos, planes, trains, etc.).

### Coal (1960)

Now—looking back to the left of the flow pattern, the reader will see that in 1960 total domestic coal production was less (in heat equivalent) than oil or gas. This coal production was equivalent to about 5.3 million barrels of oil per day. A large amount of coal (2.0) was used to generate electricity—in fact, more than half of the Nation's electric energy in 1960 was generated by burning coal. A relatively small amount (0.5) was exported—primarily for metallurgical purposes to Europe and Japan. About the same amount of coal (0.5) was used, primarily for heating purposes, in the “*residential & commercial*” end use, and only a trace (0.1) was used in “*transportation*” (we still had some coal-fired railroads operating in 1960—mostly in the West and in freight service). The largest single use of coal (2.3) was in the “*industrial*” sector—iron and steel production, etc. Also notice we used some coal (0.1) in the “*non-energy*” sector.

### Gas (1960)

Now back to the left of the chart, the reader will notice that the country's total gas supply (5.9) was composed of domestic sources (5.8) and only a trace (0.1) of imports. Some gas (0.8) was already being burned under boilers to produce electric energy. A great deal of gas (2.0) was utilized in “*residential & commercial*” end use, and the largest single use (2.8) went to the “*industrial*” sector—note that in 1960 industry already received more energy from gas (2.8) than from coal (2.3). Some gas (0.2) was used in the “*non-energy*” sector. A small amount of gas (0.2) was used in the “*transportation*” sector—primarily as energy to operate pipe lines.

### Hydroelectric (1960)

Back to the left of the chart, the reader can see that the Nation's final “*supply*” contribution in 1960 came from hydroelectric power (0.3). The United States had no significant production of energy for nuclear, geothermal or other energy sources in the year 1960.

### Electrical Energy (1960)

Next, the reader should look about a third of the way over in the top of the chart in the region indicating the “*form of use*” of energy and notice that the total “*unit*” input (3.4) into “*electrical energy generation*” for the year 1960 consisted of oil (0.3), coal (2.0), gas (0.8), and hydroelectric (0.3). The Nation lost, in our conversion process from heat to electricity, almost two-thirds (2.3) of our total input into our electric generation system. This loss is shown as “*conversion losses*.” Such losses are not unusual. For ex-

ample the maximum conversion efficiencies in conventional steam electric plants is about 40 percent.

About half of the actual electricity generated was transmitted to the “*residential & commercial*” (0.5) end use, and slightly more (0.7) was utilized by the “*industrial*” sector.

Notice that in the year 1960, we could not even draw a “*flow*” line indicating electricity use by the “*transportation*” sector—our East Coast electrified railroad grid and the various electrically driven mass transportation systems did not utilize enough electricity during 1960 to be represented on this flow pattern.

### End Use “Efficiencies” (1960)

If the reader will examine the efficiency with which each “*end use*” sector converts the total energy supplied it to useful work, he can complete the flow pattern for 1960. Notice that the least efficient user was the “*transportation*” end use sector. This sector, with an input from oil (5.0), coal (0.1), and natural gas (0.2) for a total of (5.3), lost or rejected over 75% (4.0) of the total heat energy supplied to it. Accordingly, only about 25% (1.2) was actually converted to useful work moving our autos, trucks, trains, aircraft, and ships. This alarmingly low “*efficiency*” is primarily the penalty that we pay for the methods we use to obtain our mobility.

The “*industrial*” sector in utilizing its total input (7.1), lost about 30% (2.1), while effectively utilizing almost 70% (4.9) of the total energy supplied to this sector in the form of oil, coal, gas and electricity.

The “*residential & commercial*” sector took its total input (5.0) and lost about 30% (1.5) while utilizing nearly 70% (3.5).

Finally, if the reader will examine the overall efficiency of the system in 1960, he will notice that the total losses, or “*lost energy*,” were made up of the “*conversion losses*” (2.3) from electrical generation and the losses from the “*residential & commercial*” (1.5), “*industrial*” (2.1), and “*transportation*” (4.0) sectors, for a total of 9.9 “*units*” rejected during the year. Our useful energy was made up of that actually utilized in “*residential & commercial*” (3.5), “*industrial*” (4.9), and “*transportation*” (1.2), for a total of 9.6 “*units*” of energy in the year 1960. We actually lost about 51% and utilized slightly over 49% of the total fuel energy consumed in this country.

(NOTE: On occasion the numbers on the displays will appear not to total correctly. This is due to the large numbers of mathematical conversions made and to “*rounding off*.”)

### Energy Flow Pattern (1950)

Keep **Fold-out "B"** extended so it can be referred to, and pull out **Fold-out "A."** This is a chart of the energy flow pattern of the United States in the year 1950. Notice that the physical size of the chart, along the vertical scales, indicates that the total energy consumption patterns in the United States in 1950 were already about 75 percent of what they became by 1960.

The main purpose for displaying the energy flow pattern for 1950 is so that the reader can see the relatively small amount of energy consumption in the decade of 1950 to 1960 as compared to the consumption patterns that the United States has sustained since that time.

### Energy Flow Pattern (1970)

Fold in **"A"** and **"B"** and then open **Fold-out "C."** This is a chart of the energy flow pattern of the United States as it actually took place in the year 1970. The display for this year is again to the same scale as that used for 1950 and 1960. Notice the overall growth of the energy factors. The reader need not go through as much detail for the year 1970 as he did for 1960, but there are certain major points of interest that should be noticed.

The decade between 1960 and 1970 will probably be noted for two things—first, it was the decade of a massive expansion in the use of natural gas, and, second, it was the early stages of the "take-off" in the United States move toward greater use of electricity. While oil use increased just under 50% (from 9.7 to 13.9) and coal increased slightly over 40% (from 5.3 to 7.4), the use of natural gas almost doubled (from 5.9 to 10.7).

Notice to the top and left of the diagram where under the "supply/demand" portion for the first time one can draw lines representing nuclear (0.1) and geothermal (0.003) energy.

Electric energy more than doubled in that decade (from 3.4 to 7.1). For the first time one could show an electric use (0.007) flowing from the "electrical energy generation" section to that of "transportation."

Other things to note are the disappearance of coal in the "transportation" sector, the major decrease of coal in "residential & commercial" end use (down to 0.2 in 1970 from 0.5 in 1960), and that significant natural gas (0.3) and coal (0.1) were by then used in the manufacture of "non-energy" products (mostly for fertilizer and plastics).

To the extreme right of **Fold-out "C,"** the reader will notice that "lost energy" (14.7) for 1970 was actually slightly less than the

"used energy" (15.0). The efficiency of our National overall energy conversion for the year, 1970 and 1971 may well turn out to be the best for many decades. The United States used about 50.5% and lost about 49.5%. These were the last years of the relatively efficient high compression automotive engines which required tetraethyl lead in gasoline. Also, the Nation had not embarked upon efforts to "clean up" the internal combustion engine or electric power production facilities with the resulting penalty to fuel consumption efficiency.

### Energy Flow Pattern (1980)

Fold in **"C"** and then open **Fold-out "D."** This is a chart of the national energy flow pattern as projected for the year 1980. These particular projections are based upon the National Petroleum Council's and the Department of Interior's work,<sup>3</sup> as interpreted by the Lawrence Livermore Laboratory. The reader should bear in mind that while the Nation is less than a third of the way from 1970 to 1980 calendarwise, it is already basically committed to what its energy use patterns will be in 1980 (barring major changes in the national or international area). There are many reasons for the high degree of confidence in the predictability of 1980. For instance, the Nation has already ordered a large part of the electrical capacity that can be functioning commercially by the year 1980; it has already ordered every major rail-based mass transit system that can be functioning by 1980; and the public still continues to commit the United States to an ever-increasing number of automobiles with their known poor energy consumption patterns.

Notice how projections shown on this "Fold-out" anticipate that almost 50% (10.0) of our oil requirements will be imported, and slightly over 50% (11.5) will be from domestic sources. This, of course, is a massive increase in imported oil from 1970 (3.5). Also notice that by 1980 the impact of nuclear energy should become a very significant factor in the overall U.S. energy picture.

The reader should notice the projection for the first coal gasification plant—it is represented about one-third of the way through the portion of the diagram depicting the flow of energy from coal and is shown as a "coal-gas" project with an input of 0.2 units, a useful conversion of approximately 0.13 units into gas, and a conversion loss of 0.07 units that is lost as "rejected energy".

Finally, of note is the deterioration in the Nation's efficiency of converting and utilizing energy. Anyone who has a full-size 1973

<sup>3</sup>See Appendix: Ref. 1, Ref. 2, and Ref. 3.

automobile is aware of the effects of attempting to clean up the internal combustion engine—many similar moves are being made in an effort to improve the environment, or accomplish other desirable goals, with a resultant increase in energy consumption due to decreased efficiency of energy conversion. For example, our continuing move to generate electric power in less polluting ways adds to these energy losses.

#### Energy Flow Pattern (1990)

Fold in “D” and open *Fold-out* “E.” This is a projected energy flow pattern for the calendar year of 1990. The projections necessary for developing this energy flow pattern are a very crude “average” of those made by several sources. Again, the Lawrence Livermore Laboratory compiled the majority of the basic information. The reader must understand the great uncertainty of projections a decade or so in advance and also should consider that a majority of the information used is supplied directly by the industries involved. The United States Government does not have the facilities for a completely independent evaluation of certain of our various resources.

As a country, we might be able to make some significant changes in our supply and use pattern by the year 1990, but again, as is the case through the year 1980, these changes cannot be made as quickly and as easily as many people think. Indications are that unless drastic and immediate action is taken on several fronts, our reliance on imports of energy will actually be greater than indicated on the *Fold-out* for the year 1990 even assuming the supplies and demands of the other nations of the world will continue to be compatible with our national energy requirements.

There are several items that the reader should note on this particular energy flow pattern. In the area of “supply/demand” one can see that imported oil has been projected to far exceed that anticipated from domestic sources. Also note the first real impact of oil from shale and a larger growth of gasification of coal is projected. We should be operating liquid-from-coal plants by that time and have several oil-to-gas projects in being. Our Nation’s use of coal should continue expanding quite rapidly assuming we are able to solve mining and sulphur-related environmental problems. For the first time the reader will notice the anticipated significant dependence on imported natural gas (4.0 units out of a total of 12.0 units) mostly in the form of LNG\* and SNG\*. In 1990, the continuing growth in the electrification of the United States

\*Liquid Natural Gas (LNG), and Synthetic Natural Gas (SNG).

is noted, with about a 6% annual increase in fuel requirements for the generation of electricity. The increase in electrical generation plus our anticipated continuing increase in transportation uses (as much as 3½% per year) will result in an increase in the overall conversion losses to almost 55% (35.0 units out of a total of 62.8 units). The efficiency in our overall use of energy is expected to drop from a peak of slightly over 50% in 1970 to about 45% by the mid-1980’s or 1990. [Fold in “E.”]

#### Recent Growth Patterns

A comparison of *Fold-outs* “A,” “B,” “C,” “D,” and “E,” reveals important trends in certain energy factors. Keep in mind that all charts are drawn to the same scale so the actual dimensional changes represent the growth patterns in this country in a period of 40 years. Using the same display technique, one would indicate a total energy flow pattern immediately after World War I about 45% the size of the one for 1960. A chart representing the flow patterns for 1940 would be about 53% the size of the one for 1960, and the one for 1950, shown on “A,” would be about 75% the size of the one for 1960. Somewhere in the mid-1950’s the United States “took off” on its energy consuming growth which laid the foundation for much of our energy dilemma.

The graphical data projects a six-fold increase in electric generating capacity from the year 1960 to 1990 (3.4 “units” of supplied energy in 1960 up to at least 22.5 units in 1990). Trends indicate that from the year 1970 through about 1982 or 1983, the United States will use as much oil and gas as it had used from the beginning of its history until the year 1970. To compound the problem, much of the rest of the world itself now has energy consumption patterns that are growing at a faster rate than our own. It now appears that the world as a whole will use as much energy from all forms between the period 1970 until the year 2000 as it did from the start of mankind until 1970. It is this massive growth in the use of fossil energy fuels that has mainly created the “energy dilemma” which exists in the United States and throughout the world. [Fold in “A,” “B,” “C,” “D,” and “E.”]

#### Other Uses For “Energy Display”

A device for displaying the various energy factors as has been described can be useful in planning our national energy research and development programs and our tax and production incentive policies, etc., by showing the overall impact of specific recommendations for improving our utilization and conservation of energy.

As an example of the usefulness of the device, we will examine the effect of fully insulating all of the homes and buildings in the United States by 1990 on the amount of imported oil the Nation would require.

To evaluate this proposal, the readers should open *Fold-out "E"* and start with the "residential & commercial" end use (14.5 units) item. Assume that 60% of this total applies to space heating and cooling of homes and buildings. The heating and cooling requirements would therefore be a maximum of 8.7 units. If we were to insulate fully and successfully every structure in the United States by then, we would probably reduce the heating and cooling load by a maximum of 20% (new structures may be improved as much as 40%, but many old units could only be improved 10%). Our total savings would therefore amount to approximately 1.7 units during the year 1990. If one were to assume that all of this saving would result in a reduction of oil use into residences and commercial structures (3.1), then we would apply the 1.7 savings to our anticipated imports of 18.0 units and would therefore have an overall savings in our oil imports of just under 10%. In light of the interchangeability of energy for heating and cooling, particularly when one considers energy converted to the electrical form, it may be appropriate to evaluate the impact of the savings of 1.7 units due to insulation relative to our total estimated needs of all energy forms in 1990, which is indicated to possibly be about 68.5 units. The 1.7 units would therefore result in a savings of about 3%.

Bear in mind that the "Energy Display" device is not designed to evaluate the capital cost of the proposed "solutions" to our energy dilemma—that must be done independently. The example of the impact of insulating homes and other buildings may appear to be discouraging in its evaluation if capital costs are considered. This is not to suggest that we do not increase the insulation in structures—such obviously is desirable to the extent that we can afford it. This example should serve to point out, however, that no single approach of this nature is going to solve our energy dilemma all by itself. [Fold in "E."]

#### Construction of "Cross Plots"

Now if the reader would visualize "intersecting" the energy flow patterns for each year with "cross plots" at right angles in the four areas indicated on *Fold-out "A"*, one could construct "cross plots" or graphs showing the changes in "supply/demand," "form of use," "end use," and "efficiency" over the years from 1950 through 1990.

Now pull out *Fold-out "F."* It is a sketch of how this is done mechanically. Visualize standing up each of the five "energy flow patterns" that have already been examined, and space them with a proportionate distance between each for the years represented. The sketch on *Fold-out "F"* shows how the "efficiency" plot would be prepared. [Fold in all material.]

#### Cross Plot—"Efficiency"

Pull out *Fold-out "G."* This is the "efficiency" cross plot resulting from the construction process just described. The reader can relate this efficiency curve, for example, to that part of *Fold-out "D"*, where in 1980 the rejected energy (or loss) was 23.3 units and the useful energy was 19.9 units and the total consumption was thus 43.2 units. The reader may see how one can then take the information presented on these various cross plots and convert it to whatever form is wanted. For example, one could convert the "units" shown on the "efficiency" cross plot to approximate percentages and present the information as in the following table:

Year	Total energy to consumer (units)	Percent used	Percent wasted
1955.....	16.2.....	48.7.....	51.3
1960.....	19.5.....	49.2.....	50.8
1965.....	24.0.....	50.4.....	49.6
1970.....	29.7.....	50.5.....	49.5
1975.....	36.3.....	46.8.....	53.2
1980.....	43.2.....	46.1.....	53.9
1985.....	52.0.....	45.1.....	54.9

#### Cross Plot—"End Uses"

Now fold in all charts in use and pull out *Fold-out "H."* It is a cross plot intersecting all of the annual energy flow patterns where indicated as "end uses" on *Fold-out "A"* (Energy Flow Pattern—1950). This one shows the growth over the years of the energy uses in the various sectors of the national economy. For example, notice how "transportation" has grown from 5.3 units in 1960 to 12.0 units in 1980. Notice how "residential & commercial" has grown from 5.0 in 1960 to 9.9 in 1980. "Transportation" almost triples in that period, while the "residential & commercial" sector will not quite double.

### Cross Plot—"Form of Use"

Put away "H" and open *Fold-out "I."* This cross plot is constructed so that the reader can see changes in the "Form of Use" of energy as it is made available for consumption by the consumer. Our liquid use (primarily oil) will have grown from just under 10 units in 1960 to over 19 units in 1980. Generated electricity will go from 1.2 units in 1960 to about 4.9 in 1980. This chart should give the reader an idea of the massive requirements we have facing us for the handling of these various forms of energy. For example, handling fuels in liquid form will require pipelines, tankers, import terminals, refineries, etc. Handling fuels in solid form normally requires railroads. Our massive electrification efforts will require large investments in generating plants, copper and aluminum wires for transmission, distribution, etc. [Fold in "I."]

### Cross Plot—"Supply/Demand"

Open *Fold-out "J."* This is a "supply/demand," or S/D, curve that is drawn by intersecting all of the annual energy flow patterns at the left hand side of each diagram. In the resulting chart we have changed to cross-hatch patterns on the imported oil and gas so that the reader can more readily distinguish imports from our domestic sources. The reader can review how this cross plot was constructed by comparing certain of the numbers shown vertically on the "S/D" cross plot with those on the left hand side of the appropriate years on *Fold-outs "A" through "E."* [Fold in "J."]

It was found desirable to include a series of energy "supply/demand" charts in which oil and gas fuel imports are combined to indicate the total deficiency in our domestic supplies of energy. The following sections describe these charts.

#### "Supply/Demand" Chart (From "Energy Display")

Open *Fold-out "K."* This chart is constructed by taking the information shown on the "supply/demand" cross plot and eliminating the blank spaces between the different sources. The rise shown in the domestic oil in the lower right hand part of the graph would be from Alaska oil if such were to be brought into production by 1977.

#### "Supply/Demand" Chart (1960 through 1985)

Now fold back "K" and pull out *Fold-out "L."* This particular chart is basically the same as the one the reader has just examined. However, in this chart the "imports" of both oil and gas and their

products are now moved to the top and labeled as "imports and/or shortages." We have added the word "shortages" because the inflexibility of the supply system could result in shortages if we are unable to obtain the necessary imports for any reason.

The area marked "surplus oil" is a display of the spare productive capacity that Texas, Louisiana, and Oklahoma had once been thought to possess. Estimates of this item vary a great deal depending upon when they were made. Recent evaluations<sup>4</sup> of such "surplus" capacity are lower than ones made years ago. It is shown so that one can see how the combination of all of our "fossil fuels" (oil, gas, coal and "surplus oil") has actually resulted in a fairly predictable total over the years. Our present problems have not simply shown up overnight—we had some indication several years ago that they would develop.\*

The reader should recognize that the projections shown for imported fuels required are considerably larger than those made as recently as two years ago. The total energy demand is projected at over a million barrels a day greater by the year 1980 than was earlier estimated for that period in data compiled in early 1971. Nuclear plant completions are also falling 15% or so behind what was anticipated as recently as 1971.

Our slippage in nuclear in the year 1980 alone will require well over one-half a million barrels per day of oil *equivalent*. If such is replaced by imports (and even if we could buy it for its present price of about \$4.00 a barrel), it will result in a foreign exchange loss of almost one billion dollars during that one year alone. (See page 21 for information on how nuclear power growth estimates have increased with time.)

This estimate is based on a shortfall of 18,000 megawatts of nuclear capacity in the AEC's goal of 150,000 megawatts by 1980. The delays are being incurred primarily by matters relating to the licensing of nuclear powerplants and problems in meeting the exacting quality requirements of this new industry.

This particular chart underscores the massive nature of the problem facing the United States with reference to importing crude oil, petroleum products, and gas. For instance, it now appears that our actual cost for imported fuel in 1972 resulted in an outflow of at least \$7.5 billion, offset with a return of somewhat over \$3.5 billion from dividends, etc., of the multi-national com-

<sup>4</sup>See Appendix: Ref. 4.

\*See Joint Committee on Atomic Energy hearings, "Development, Growth, and State of the Atomic Energy Industry," February and April 1963.

panies involved in overseas energy operations. Projections based on this chart indicate that in 1973 our energy purchases from overseas will probably exceed an outflow of \$9 billion. In 1975 it will probably exceed \$13 or \$14 billion. By 1980 the purchases will approach a minimum of \$20 billion, and by 1985 at least \$30 billion. These numbers are based on the precarious assumptions that oil, gas, and petroleum products will still be sold to us at today's prices and that it will be readily available to the world in such massive quantities.

A recent article in the *New York Times*<sup>5</sup> quotes recent projections of Ford, Bacon and Davis, Inc., in which they expect over \$14 billion will be the deficit costs for oil imports during 1975, \$30 billion by 1980, and \$54 billion by 1985. This particular article goes on to comment:

*"The projections are fantasies. Long before 1985, such import needs will bankrupt America, eliminating us as a customer."*

A publication just released by one of the major international oil companies<sup>6</sup> projects that the range of costs of U.S. oil imports in the year 1985 will range from at least \$30 billion per year to as much as \$70 billion per year. [Fold in "L."]

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This concludes the description of the "*Energy Display*" system and its associated charts. We would like to emphasize again that the material thus far presented has not been new. We have simply altered the method of displaying information hoping that it will be easier to understand.

<sup>5</sup>See Appendix: Ref. 5.

<sup>6</sup>See Appendix: Ref. 6.

#### IV. DESCRIPTION OF DISPLAY TECHNIQUES FOR LONG-RANGE "OPTION-EXERCISE" PROJECTIONS

The need for a technique of presenting long-range projections and for providing a device that will assist in evaluating possible options in meeting United States energy needs is obvious.

Despite all of the recognized dangers in making long-range projections, we consider it essential to extend energy estimates to at least the year 2000.

The first reason for this is the very nature of many research and development projects that are constantly before Congress. Many of these projects have lead times of decades before they will really impact on the American energy picture.

The second reason for such projections is not as immediately apparent. It has to do with the very thrust of what may be the only real direction for America to go with its future energy strategy. The Nation is actually finding itself in the "*twilight*" of the fossil fuel age. We have used the cream of our oil, gas, and coal resources as one of the basic building blocks of a technical and industrial society the likes of which the world has never seen. We will now have to use our technical capacity to carry ourselves into the next "*age,*" or "*era.*" We can make this transition primarily by buying time through the next few decades through accelerated uses of our remaining domestic fossil resources (particularly coal, oil, gas, and oil shale) and by conserving and using our energy more wisely. The degree of determination of the Nation to do these things—our obvious moves toward development of new sources, our energy conservation programs, the price we are willing to pay (both in dollars and environmentally) for accelerating uses of domestic fossil sources, etc., can help produce the strongest posture for our Nation as it faces the energy dilemma.

##### "Guidance" Required

Open *Fold-out* "M," entitled "Guidance" Required. The approach we are utilizing involves estimating "**demand**" lines through the year 2000 and then subtracting from each the maximum amounts of "**imports &/or shortages**" that the Nation's economy can tolerate. These are the two general but basic guidelines that must be delineated by our Government in order for technicians and engineers to "exercise" the various options concerning domestic energy sources that are available for filling the domestic energy requirement. [Fold in "M."]

### Forecast of Energy Demand to Year 2000

Open *Fold-out "N."* This chart displays several of the more recent appraisals of the Nation's energy demand through the year 2000.<sup>7</sup> There are several other recent projections that call for even larger energy consumption than those shown on this chart but in order for such to take place, it would require a massive commitment to the all but total electrification of the Nation.

The reader will notice that the Nation is now using the oil equivalent of about 36 million barrels per day. This is very close to the "high forecast" as shown on *Fold-out "N."* If the Nation continues on its present growth rate decreased by one-tenth of 1% every decade, we would reach an energy "demand" of almost 120 million barrels per day oil equivalent by the year 2000. The predominance of recent projections appear to estimate that the United States will require at least 95 million barrels per day oil equivalent by the year 2000. Historically, particularly over the past two decades, forecasters have consistently underestimated the growth of energy requirements in the U.S. The chart shows a population curve to give the reader an indication of the continuing relationship between population and energy use in the United States.

In an effort to be on the conservative side of these estimates, the Committee staff has carried out several "option-exercise" projections starting with low "demand" curves. Six of the exercises are based on 87.5 million Barrels Per Day Oil Equivalent (B/DOE) by the year 2000, and two on the low number of 82.0 million B/DOE for the year 2000. One such "option-exercise" will be described later in this print. The reader should understand that the Committee is in **no way** recommending that the "demand" for energy in the U.S. be curtailed to such a degree—it is fully aware of the requirements for energy to support our way of life, our jobs, and our national security. The low numbers were used for energy "demand" in order to reduce the apparent requirements for "total domestic sources" to a minimum.

[Fold in "N."]

The second "guidance" required before the "options" can be "exercised" intelligently is that of estimating the maximum imports of oil, petroleum products, and gas that can be tolerated. Attempting to eliminate imports altogether is probably unrealistic and would also compound the energy problems of the Northeastern

<sup>7</sup>See Appendix: Refs. 3, 6, 7, and 8.

section of the Nation. It may also complicate our national efforts to encourage orderly energy developments on a worldwide basis.

The "exercises" of the display system have been made assuming an "imports & /or shortages" area of approximately \$20 billion per year—again assuming the cost will remain constant and that imported fuel will be available to the Nation. This approach calls for the leveling out of the rate of imports at about 12 million barrels per day of oil equivalent.

The reader can now see how the "guidance" requirements shown on *Fold-out "M"* have been tentatively defined so that various estimates and options may be exercised concerning our domestic energy sources. If the selection of total demand and of the maximum amount of fuel imports that it is judged the Nation can tolerate is of a magnitude similar to that discussed above, a major effort in almost all of the various domestic energy sources will be required.

### Option Exercise 7-A

Open *Fold-out "O."* This is a chart of one of several different displays prepared of our national energy situation through the year 2000. We have selected OPTION EXERCISE 7-A to explain the method of presenting such data. This particular exercise is one that appears to have a relative balance in the degree of determination used in trying to assemble the required domestic energy supplies. It should be emphasized again that these displays in **no way** constitute actual proposals from the Joint Committee or its staff—the chart is shown primarily to illustrate the method of presentation developed and to give the reader an indication of the complexity and magnitude of the energy dilemma in the United States. The reader should recall that this particular display starts with the assumption of a depressed "demand" requirement which is over 25% below what would result by the year 2000 if the Nation were to continue its current growth rates in energy use. This particular display also includes an acceptance of a magnitude of "imports & /or shortages" which appears to exceed what is considered desirable by many concerning themselves with the financial security and stability of the United States.

If the reader will then start at the bottom of the chart, general information will be presented on each of the various domestic sources which was considered to meet our energy needs.

### Lower 48 Oil

This option considers domestic oil production in all the states, except what may be available from the Alaska North Slope. This is being done in an attempt to help decrease some of the misunderstanding that usually follows when an evaluation includes the North Slope Alaska production at an early stage of analysis. The United States is probably capable of predicting domestic oil production with about an 80% or 85% accuracy for a decade or so. The oil industry has a broad based experience in anticipating rate of "finding," numbers of "dry-holes," cost of production, etc. The industry is a mature one, technically capable of immediately carrying out a program for the maximum production of oil from our domestic resources. "OPTION EXERCISE 7-A" is targeted for a major, but not necessarily a maximum effort to strengthen domestic oil production. This option assumes at least a 50% price increase in domestic crude, immediate development of known off-shore deposits (Santa Barbara Channel, for example), a major increase in off-shore operations in the Gulf of Mexico, outer continental shelf operations off the East Coast of the United States, and an increased effort in the Federal lands in the Western part of the country. Few petroleum production experts would consider it appropriate to show a much more optimistic curve than the one represented on *Fold-out "O."*

### Coal

This particular option shows an almost tripling of coal production in the next three decades. This could be accomplished by a tripling of strip-mining of coal and at least a 50% increase in underground mining of coal above current rates, or other combinations of mining technology. Coal has a resource base which could apparently support even a greater increase than shown, but the availability of water, reclamation problems, fabrication limitations of the massive equipment which will be required, steel, transportation facilities, and other such items could make the coal impact shown on *Fold-out "O"* optimistic. Bear in mind that it will be impossible to evaluate the coal input into our domestic energy system until the Congress has settled on strip-mining legislation, clarified leasing procedures, etc. It will be possible, once the rules are drawn, to project coal production with a predictability of 90% or better for a few years in advance. The resource is already fairly well defined and the industry is mature.

### Domestic Gas

This one is probably the hardest to estimate. Most engineers will agree that the Nation will be fortunate if long range projections of gas availability are 50% either way of actual production. The strategy in this option would require the deregulating of both new and flowing natural gas prices to try to sustain or slightly increase our current production of gas for the next decade or so. The numbers shown here are very close to those of the Federal Power Commission, with the exception that, in OPTION EXERCISE 7-A the option tapers off much faster from the year 1985 toward the year 2000 than most estimates. It is hoped that the United States will discover a massive new gas supply but our recent history of winter supply problems, even in the State of Texas, could well be indicative that even this display is optimistic. Fortunately, any new natural gas supplies would impact quite rapidly if the reserves do exist. The United States has a fully matured gas industry that can expand rapidly.

### Geothermal

Geothermal power is probably fairly predictable, despite present technical unknowns, once the Nation has established a level of environmental problems that it is willing to tolerate and estimated the amount of capital that can be committed to the development of such power. In OPTION EXERCISE 7-A, an approach is illustrated that would have at least 100,000 megawatts capacity operating by the year 2000. The reader should recall that the display of such an "option" does not constitute an endorsement of its probability or feasibility. A geothermal input of this magnitude would require a massive effort in California, and several other States, and would generate the electric equivalent of over 100 Hoover dams.

### Hydroelectric

Hydroelectric capacity can be projected with nearly 100% reliability—once the rules are drawn. The hydroelectric equivalent shown in OPTION EXERCISE 7-A represents at least a 50% increase in today's capacity. The great majority of attractive sites are in National Parks, scenic areas, and the like. It would be necessary to build dams in such places as the Grand Canyon if the Nation were to undertake a massive effort to increase its hydroelectric systems.

### Alaska Oil

This particular estimate assumes that the Alaska (Valdez) line will be in operation in late 1977 and would reach about 1,500,000

barrels per day of oil by early 1980. It then assumes construction of an oil line through Canada in the early 1980's, with that line going on stream and at full capacity by 1984. It also assumes that considerable oil will be found in the Federally-owned Navy Petroleum Reserve #4 (on the North Slope) and that such production will be developed. The development of the preceding combination could increase domestic oil production by over 4,000,000 barrels a day. The Alaska North Slope impact is probably 80 or 85% predictable, again because the Nation is in a position to proceed and has done a great deal of work in the area already. The necessary technology exists and a mature industry is available.

### Oil Shale

Oil shale, like coal, consists of a massive resource in place. Unfortunately, however, oil recovery from oil shale may well be even more severely limited by water restrictions than production of coal will be. While the technology is basically available for above ground production, several demonstration plants may be required before financing information can be obtained for the commercial effort that will be required. Limiting factors appear to be uncertainties in the investment climate and questions with reference to leasing and using Federal lands. In order to produce even 1,000,000 barrels per day of shale oil, using surface technology, it will be necessary to have massive mines with the total daily tonnage of material handled well in excess of that of our present daily coal production. A 3,000,000 barrels per day operation in the western part of Colorado, including all of its support population and facilities, would come very close to requiring the equivalent of the total minimum water flow of several of the larger rivers of that area. No efforts are made to project impacts of various "in situ" proposals because their technology is still in its infancy. Predictability of shale operations is very close to 80 or 90% or better. A combination of basically mature industries is available for these operations. Despite its problems, oil shale may represent one of the cheapest and cleanest additions to the Nation's energy mix.

### Solar

Solar technology should permit us to soon take over some of the heating and cooling load requirements in the Southwestern part of the United States. The estimate on *Fold-out "O"* shows a 1,000,000 barrels per day equivalent from solar. This would satisfy the heating and cooling load of more than all of the houses that will exist in New Mexico, Arizona, and Nevada at the turn of the century. Pre-

dictability of solar is still fairly weak because of the requirements of developing several phases of the necessary technology and the non-existence of a mature industry at this time.

### Nuclear

A nuclear capacity build-up to over 1,000,000 megawatts by 2000 is shown on OPTION EXERCISE 7-A. This display is slightly under the latest estimate of the nuclear industry of the maximum amount of nuclear capacity which could be added over the next two decades. A table of the various pertinent estimates of nuclear capacity follows to facilitate comparisons:

Year	Capacity in megawatts*			
	AEC, 1962	AEC, 1968	AEC, 1972	AIF, 1973
1980.....	40,000.....	150,000.....	132,000.....	146,000
1985.....	100,000.....	300,000.....	280,000.....	365,000
1990.....	200,000.....	500,000.....	508,000.....	700,000
2000.....	700,000.....	1,000,000.....	1,200,000.....	

\*See Appendix: Refs. 3, 10, 11, and 12.

The 1962 estimates are presented above since they reflected the best estimates of the future need for nuclear generating capacity at the time a comprehensive nuclear power development program was delineated. A comparison of subsequent estimates indicates a twofold increase, over the period 1962 to present, in the energy goals for installed nuclear power capacity by the year 2000.

The Atomic Industrial Forum estimate was developed as the maximum which would be feasible providing the limitations presently imposed by specific factors such as licensing, development of additional uranium supplies, technical and construction manpower limitations, financing, and so forth, are significantly diminished and a massive national effort is made to develop the nuclear systems.

Although the nuclear capacity additions have been developed on the basis of considerable study, past experience with new and complex technologies indicates problems may be expected in the attainment of such a maximum goal. To attain or approach to a major degree the maximum estimates utilized for nuclear power in *Fold-out "O"* will require a massive industrial effort and major upgrading in a number of areas such as quality control performance by industry, licensing procedures, etc.

The various problems relating to the licensing, construction and operation of nuclear powerplants have already resulted in a situation where identical plants built in Japan and the United States by the same suppliers take five years in Japan, and over eight years in the United States. This option assumes a national effort to develop the required uranium supply and the various support systems for nuclear powerplants.

The one exercise described to illustrate the use of the graphic presentation to evaluate a possible solution to the energy situation clearly indicates the magnitude of effort required to maintain reasonable control of the problem. It should be recognized that many potential supply items were not displayed because of lack of available projections or information. Wind power, tar sands, and tidal sources are some such items. "OPTION EXERCISE 7-A" appears to be one of the more balanced of the several exercises examined by the JCAE staff to date. Initial reaction of the reader may lead to the assumption that an almost unlimited number of combinations of domestic energy options exists. Unfortunately, the deterioration of the Nation's domestic supply of cheap fossil fuel energy has actually severely limited the National options that are available. [Fold in "O."]

"S/D Chart" — (1900 through 2050)

Open *Fold-out "P."* This chart should enable the reader to better grasp the meaning to the United States of the difference between the "era," now ending, of relatively cheap and available domestic fossil fuels and the emerging "era" of a requirement for an ever increasing supply of non-fossil energy sources and for imported energy fuels. The reader should notice that even a significant decrease in our energy "demand" and a major increase in our domestic fossil supplies will only provide a few years respite in our Nation's energy dilemma.

Both maximum and minimum estimated "demand" curves are shown. The maximum curve reflects a demand for approximately 175 million barrels per day oil equivalent, with the United States reaching a per capita energy saturation point near the year 2075. The minimum demand curve assumes both per capita energy saturation plus zero population growth in the decade of 2030. It is necessary to again emphasize the great uncertainty of such different distant projections irrespective of their sources. The trends, not the details, are the important factors.<sup>8</sup> [Fold in "P."]

<sup>8</sup>The staff utilized at least three sources for *Fold-out "P."*. See Appendix: Refs. 13, 14, and 15.

## V. CONCLUSION

The method described in this print has been found to be of great value to members of the Joint Committee and others who have viewed the data in studying energy matters. The graphic method facilitates the evaluation of specific energy factors in context with other energy supply matters. The interchangeability of energy forms is readily evaluated from a comprehensive presentation of information on all energy forms. The method also facilitates the evaluation of specific suggestions for the solution of our energy problems. Presentation of the information on such suggested solutions in graphic form requires inclusion of information on both the schedule of availability of the energy and the magnitude factors, which are at times not given the consideration they each deserve.

The information on presentation of energy supply matters is being printed in the hope that it will be of assistance to Government officials, industry, and the public in the study of energy supply problems. The need for prompt action in a number of areas is clearly evident from the data compiled in this print. It is hoped that this information will contribute to the evaluation of various solutions and expedite decisions and actions which are required to minimize problems in these areas.

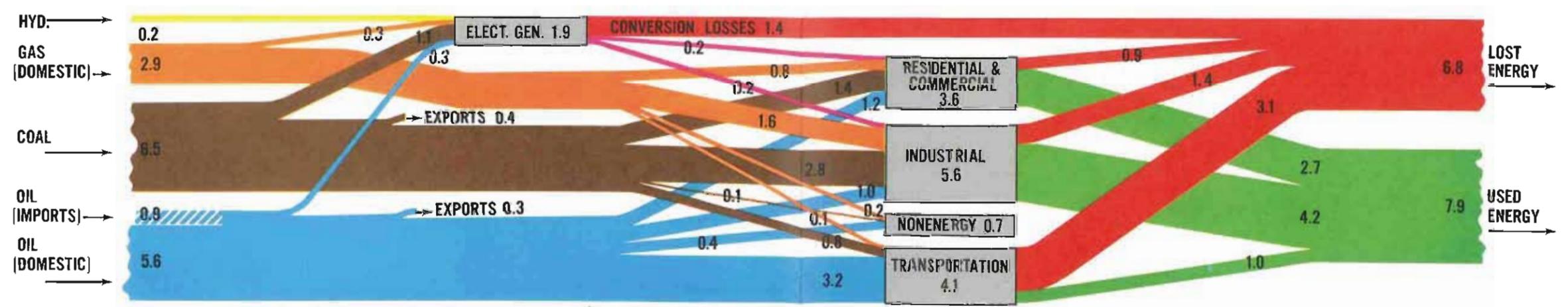
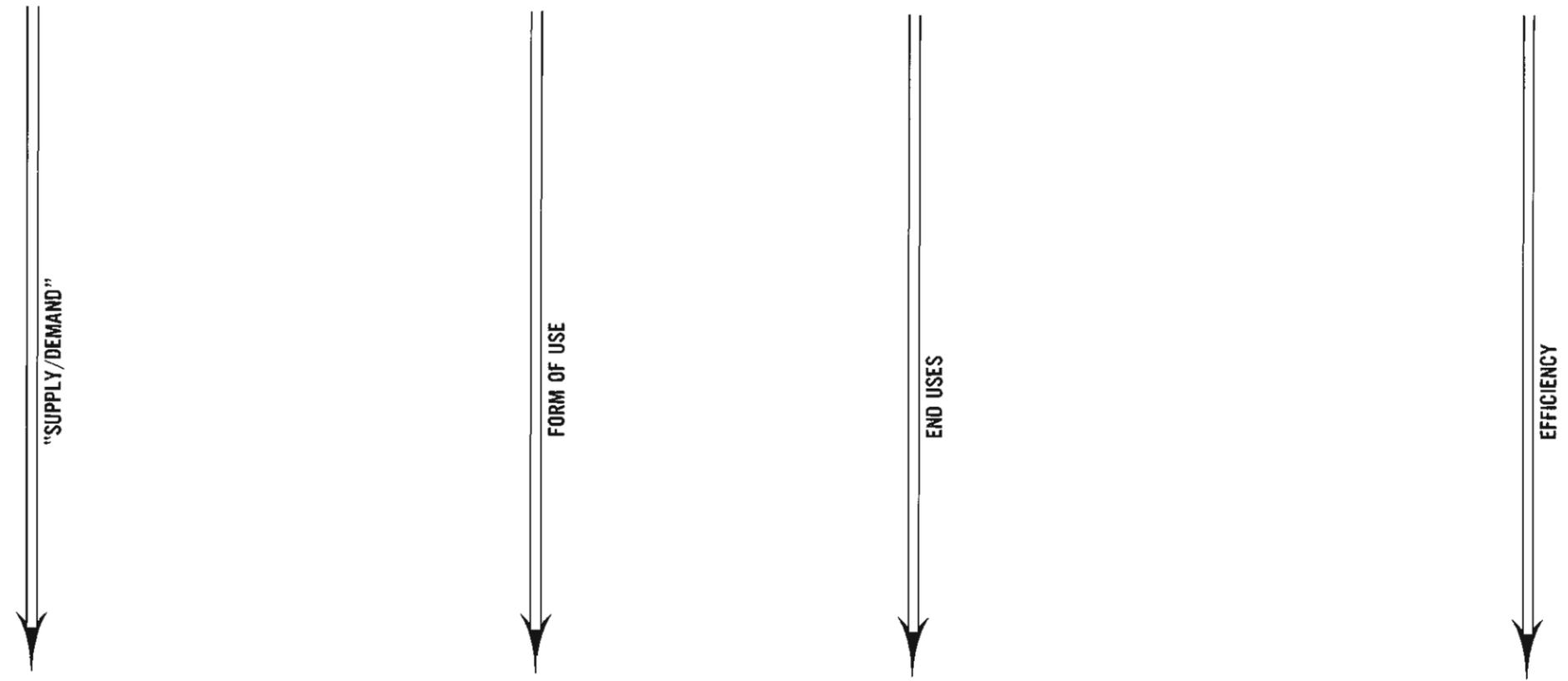
## APPENDIX

### A. References

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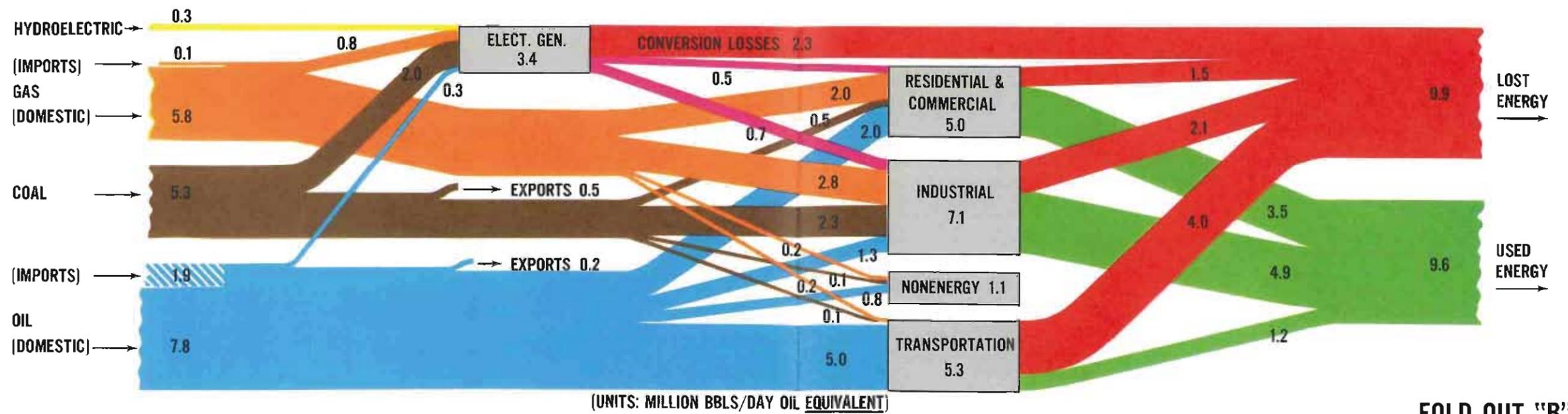
### B. Conversion Tables

- 1 Barrel (Bbl. or B) = 42 gallons (gal.).
- 1 Bbl. crude oil = 5,800,000 Btu.
- 1 kWh = 3,412 Btu.
- 1 cu ft natural gas (CH<sub>4</sub>) = 1,000 Btu.
- 1 ton coal = 26,000,000 Btu.

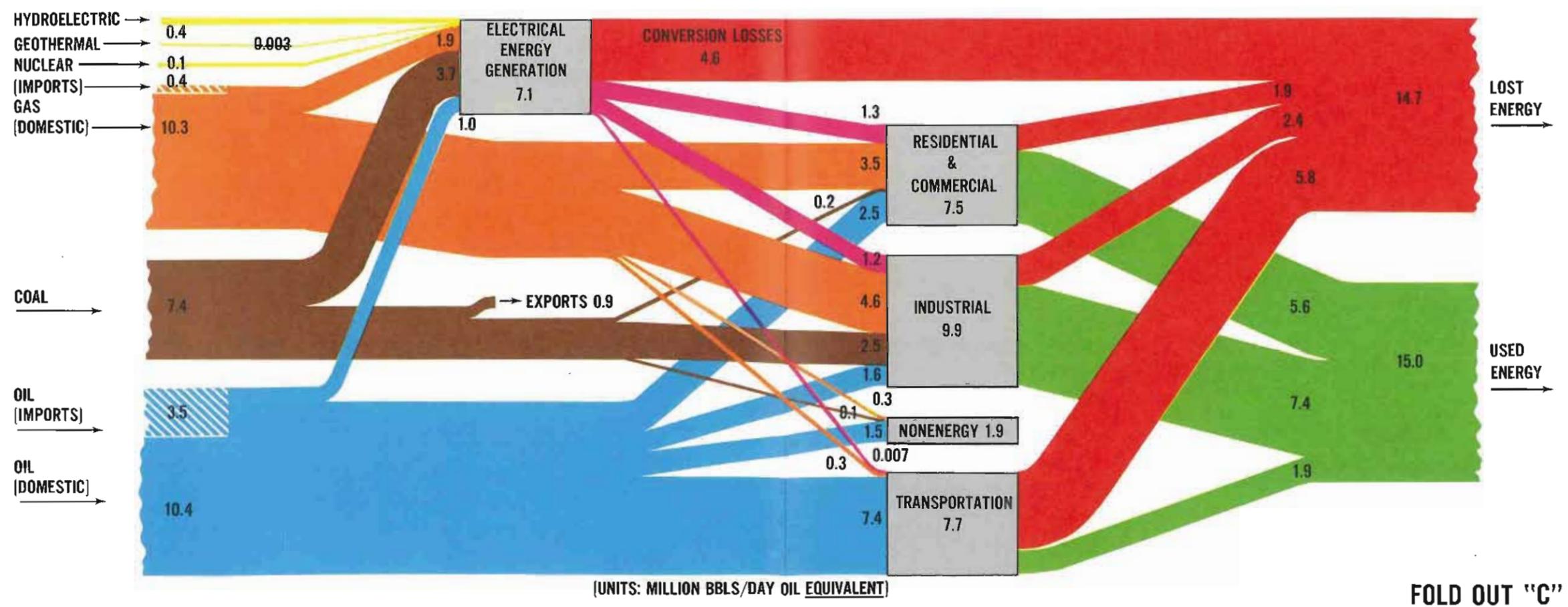


(UNITS: MILLION BBL/DAY OIL EQUIVALENT)

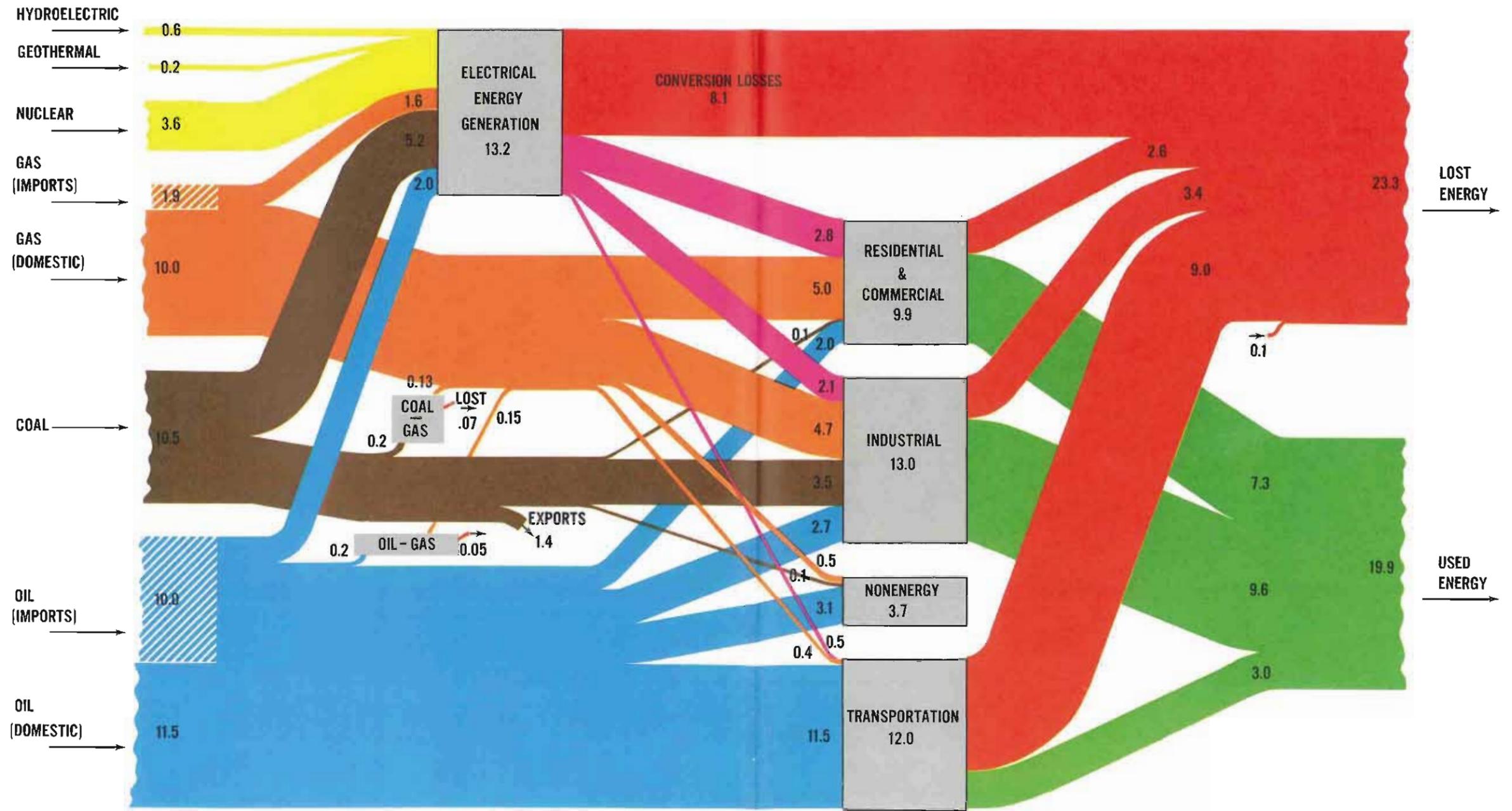
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FOLD OUT "B"

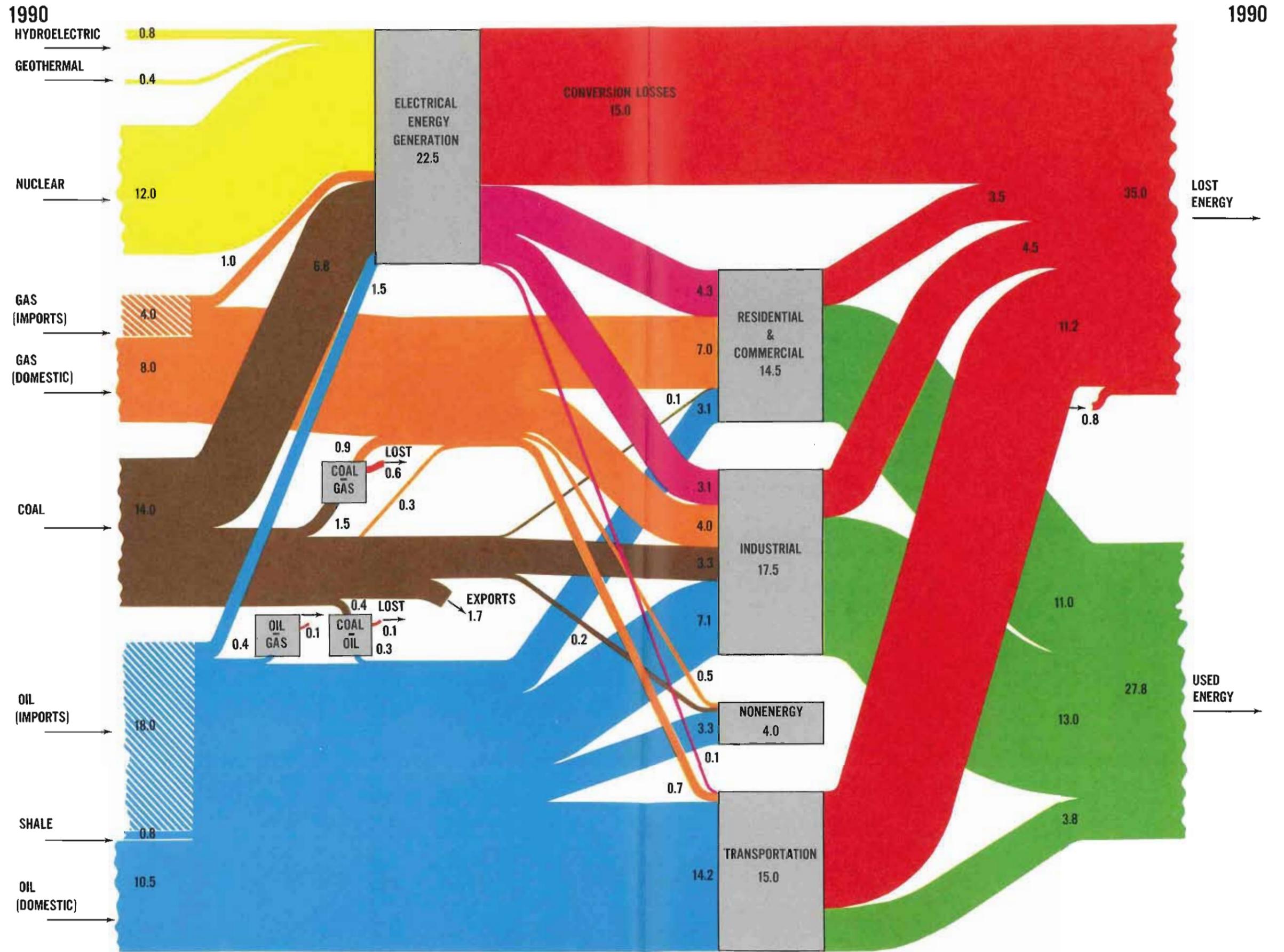


FOLD OUT "C"



(UNITS: MILLION BBL/DAY OIL EQUIVALENT)

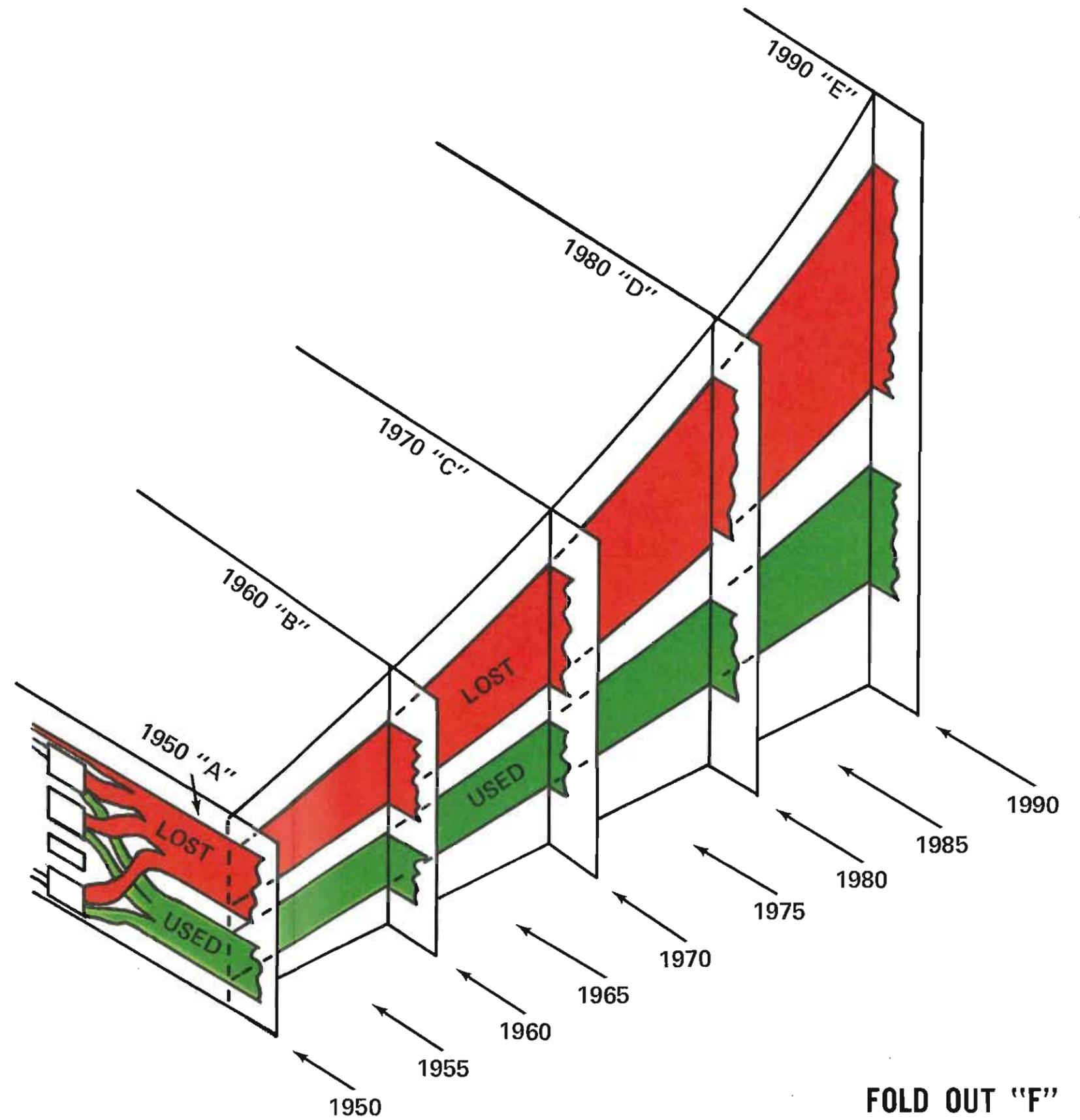
FOLD OUT "D"



**E**

FOLD OUT "E"

# CONSTRUCTION OF "CROSS PLOTS" ("EFFICIENCY" PLOT SHOWN)



1955  
↓

1960  
↓

1965  
↓

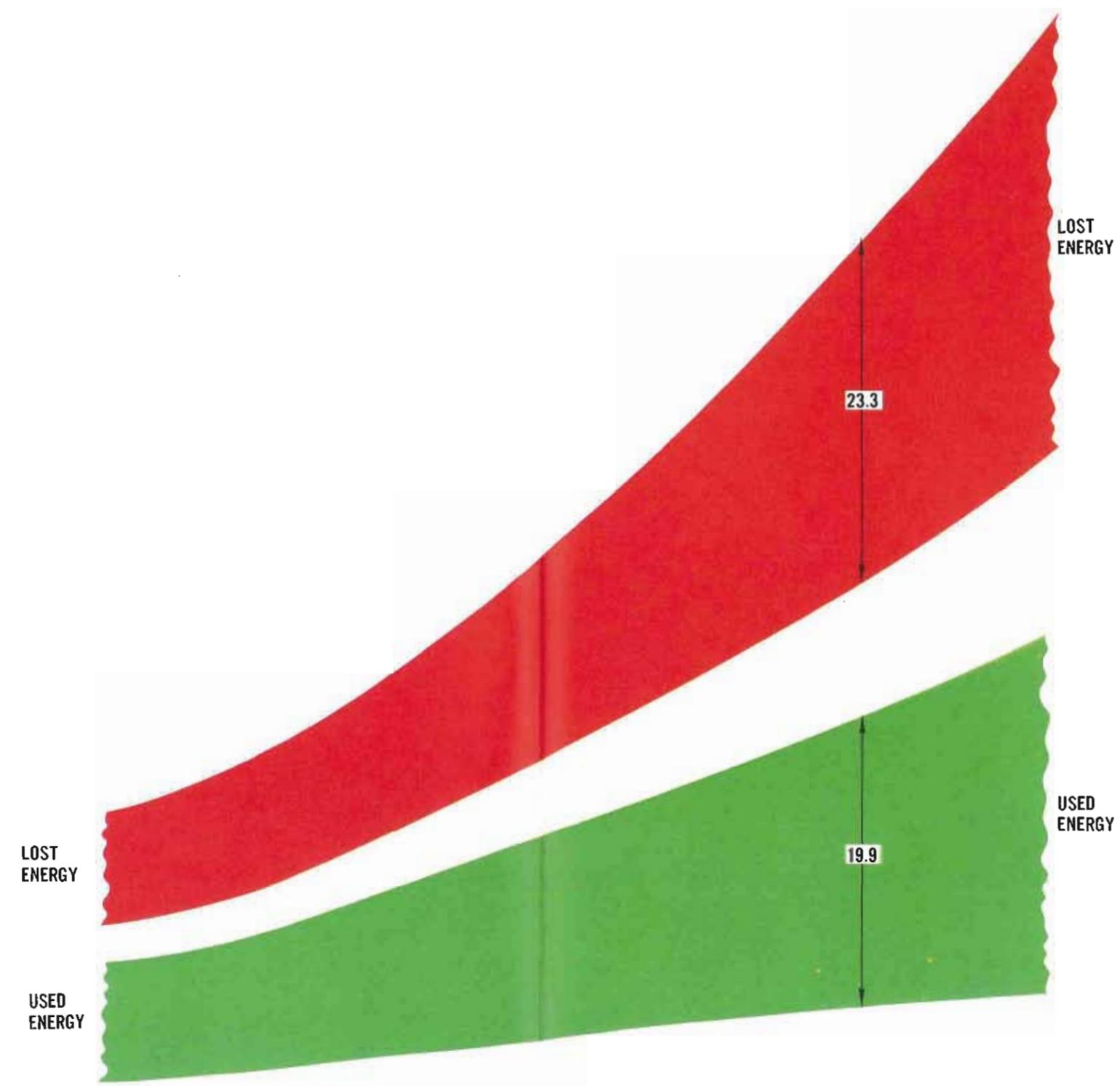
1970  
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1975  
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1980  
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1985  
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EFFICIENCY



G

FOLD OUT "G"

1955  
↓

1960  
↓

1965  
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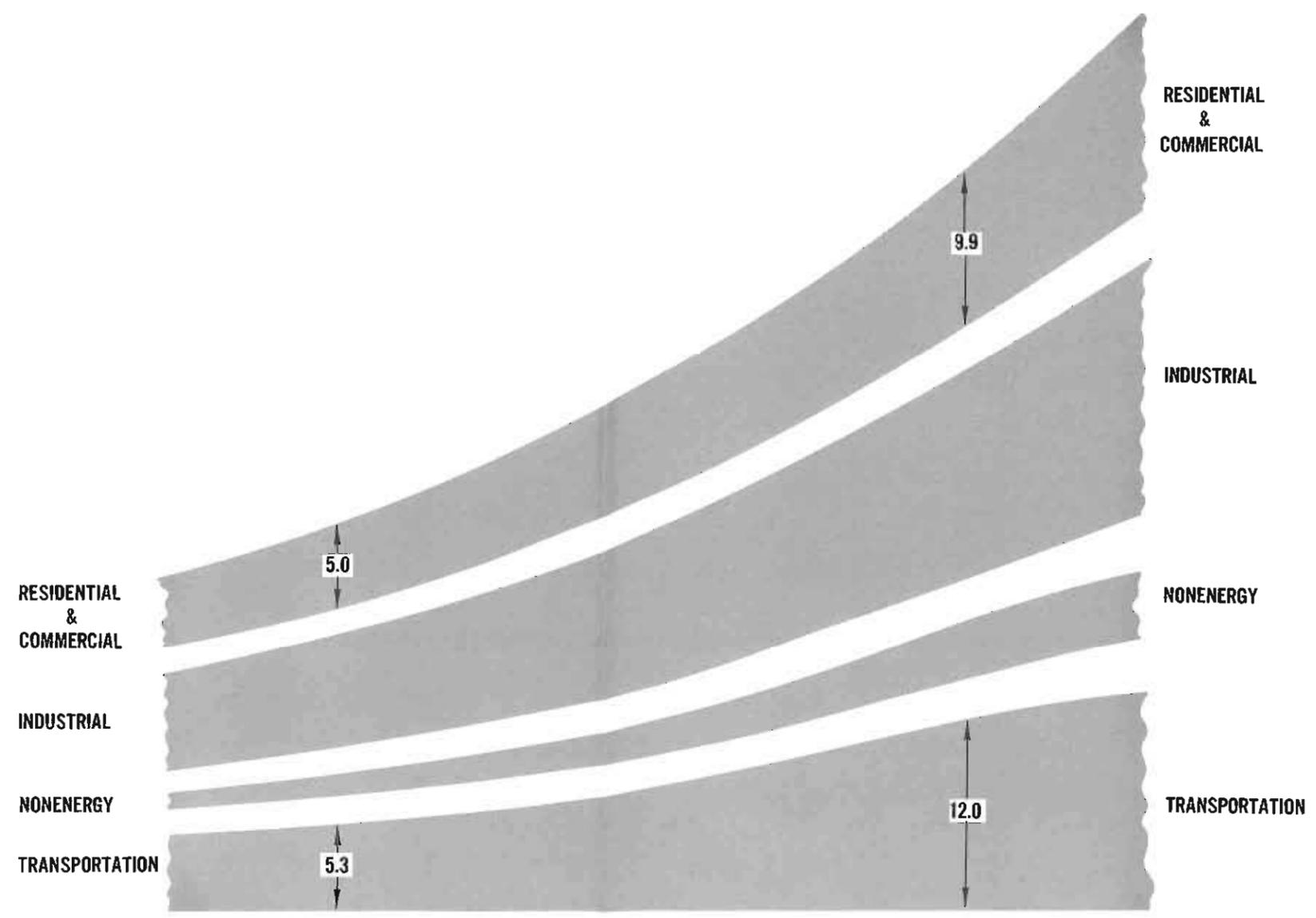
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END USES

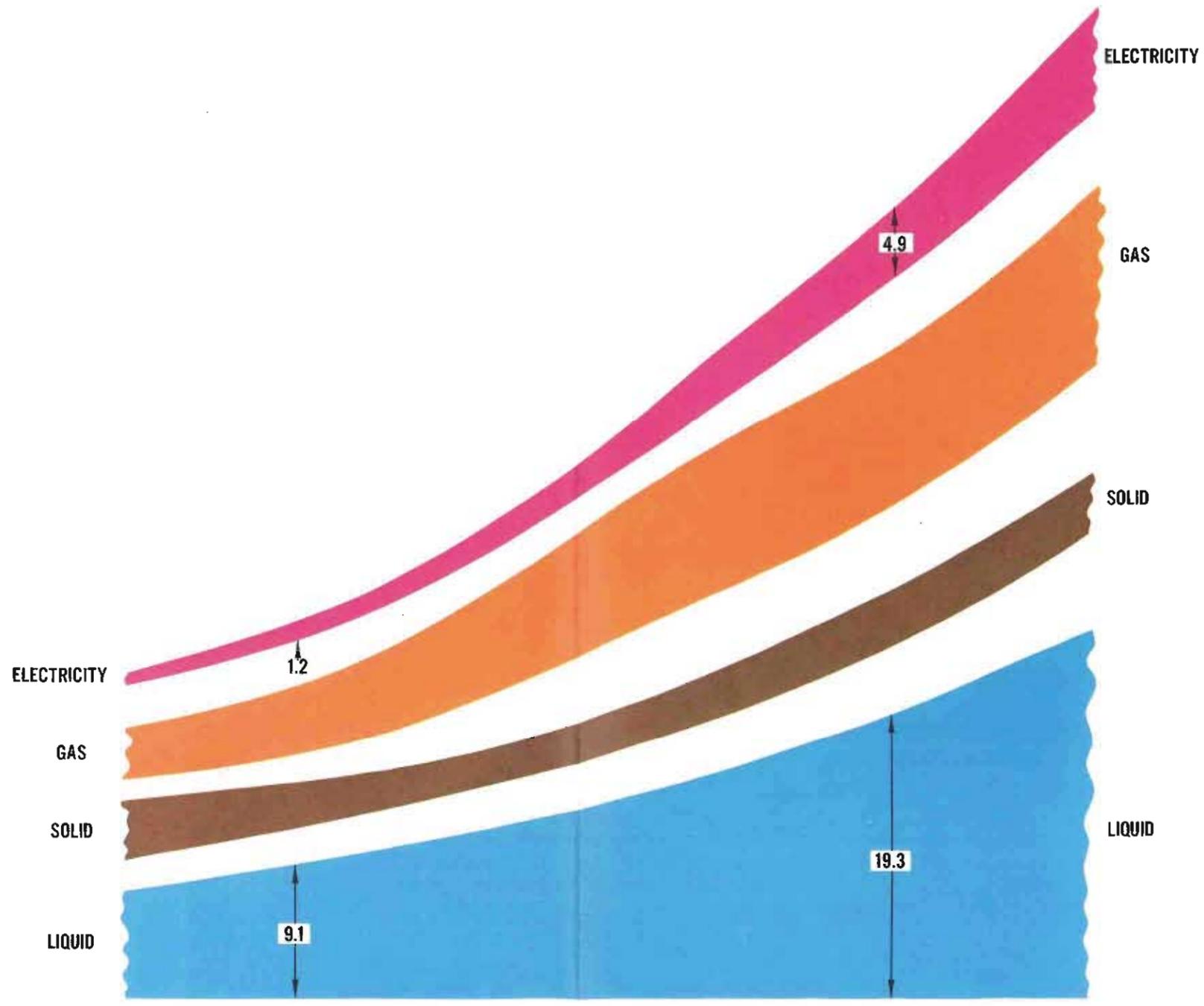


H

FOLD OUT "H"

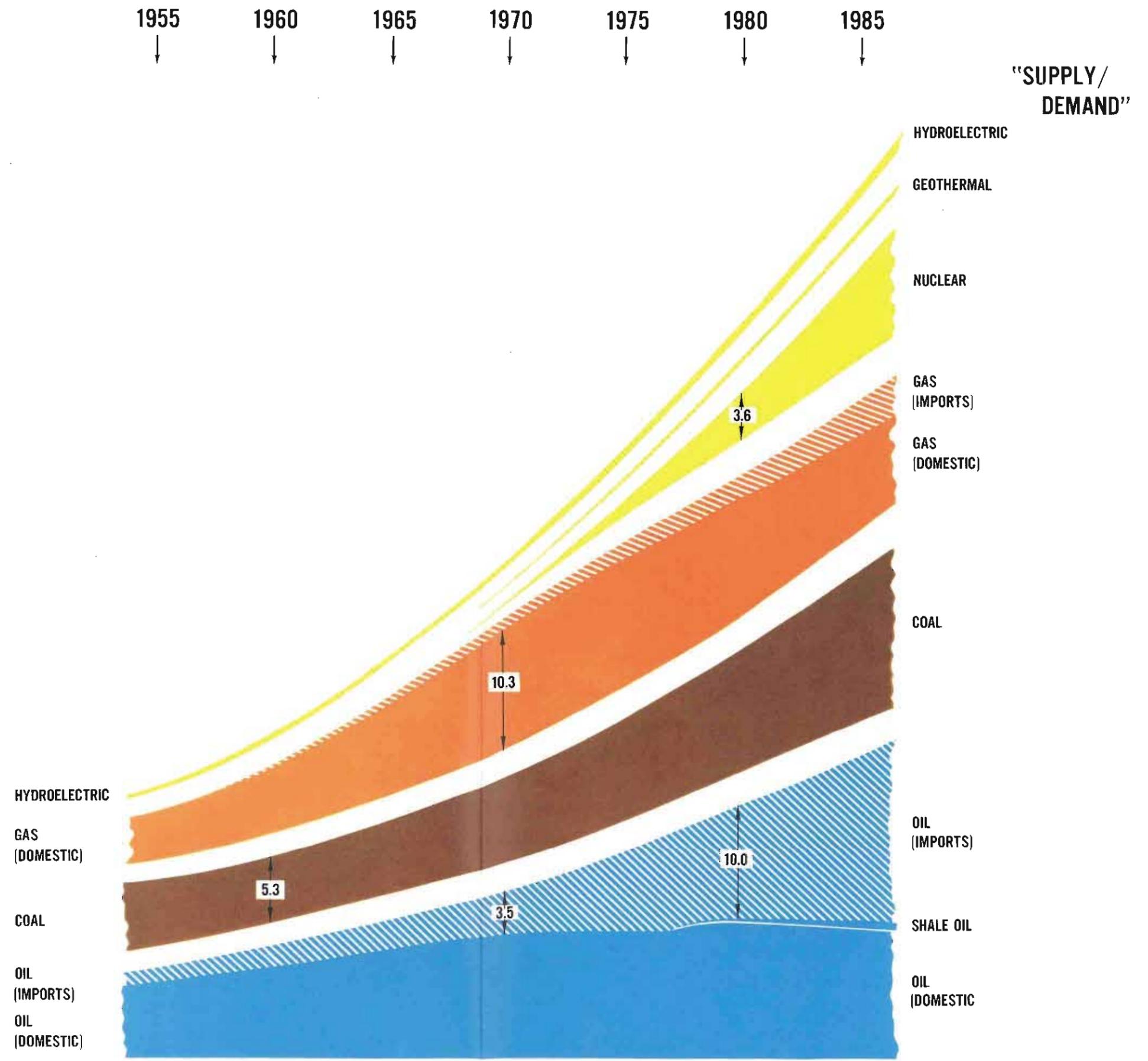
1955    1960    1965    1970    1975    1980    1985

FORM OF USE



I

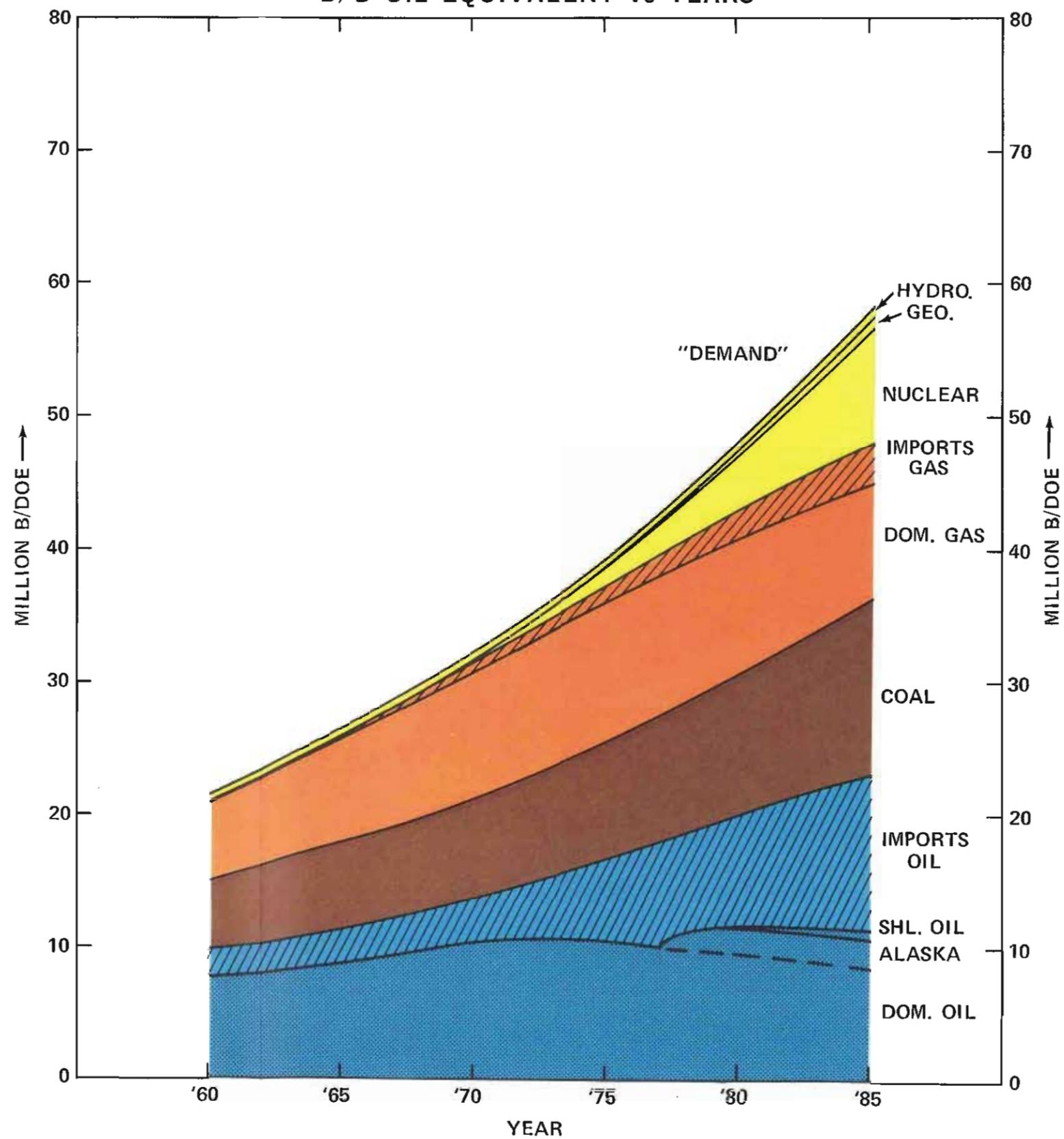
FOLD OUT "I"



**J**

FOLD OUT "J"

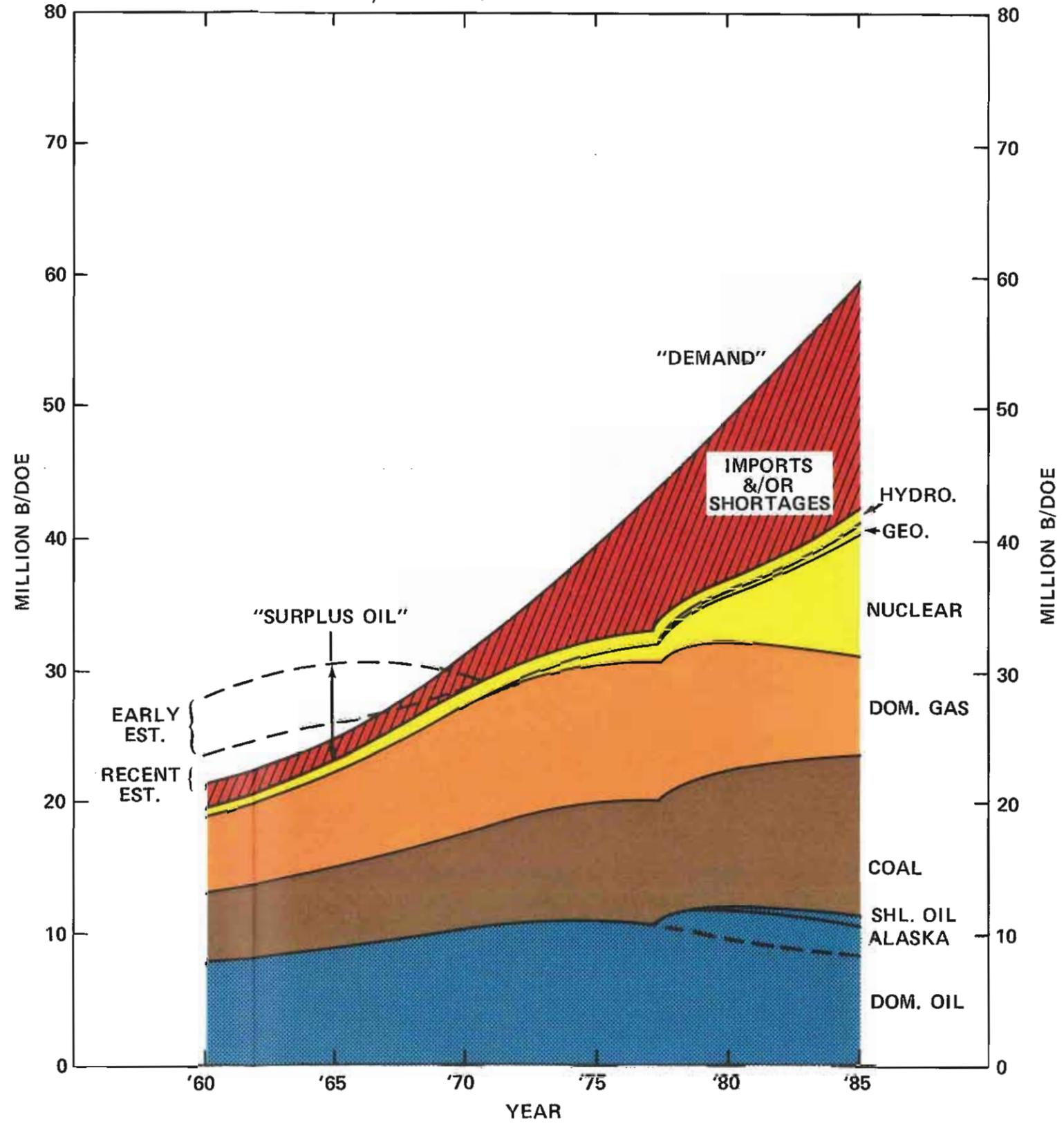
"SUPPLY/DEMAND"  
(FROM "ENERGY DISPLAY")  
B/D OIL EQUIVALENT vs YEARS



K

FOLD OUT "K"

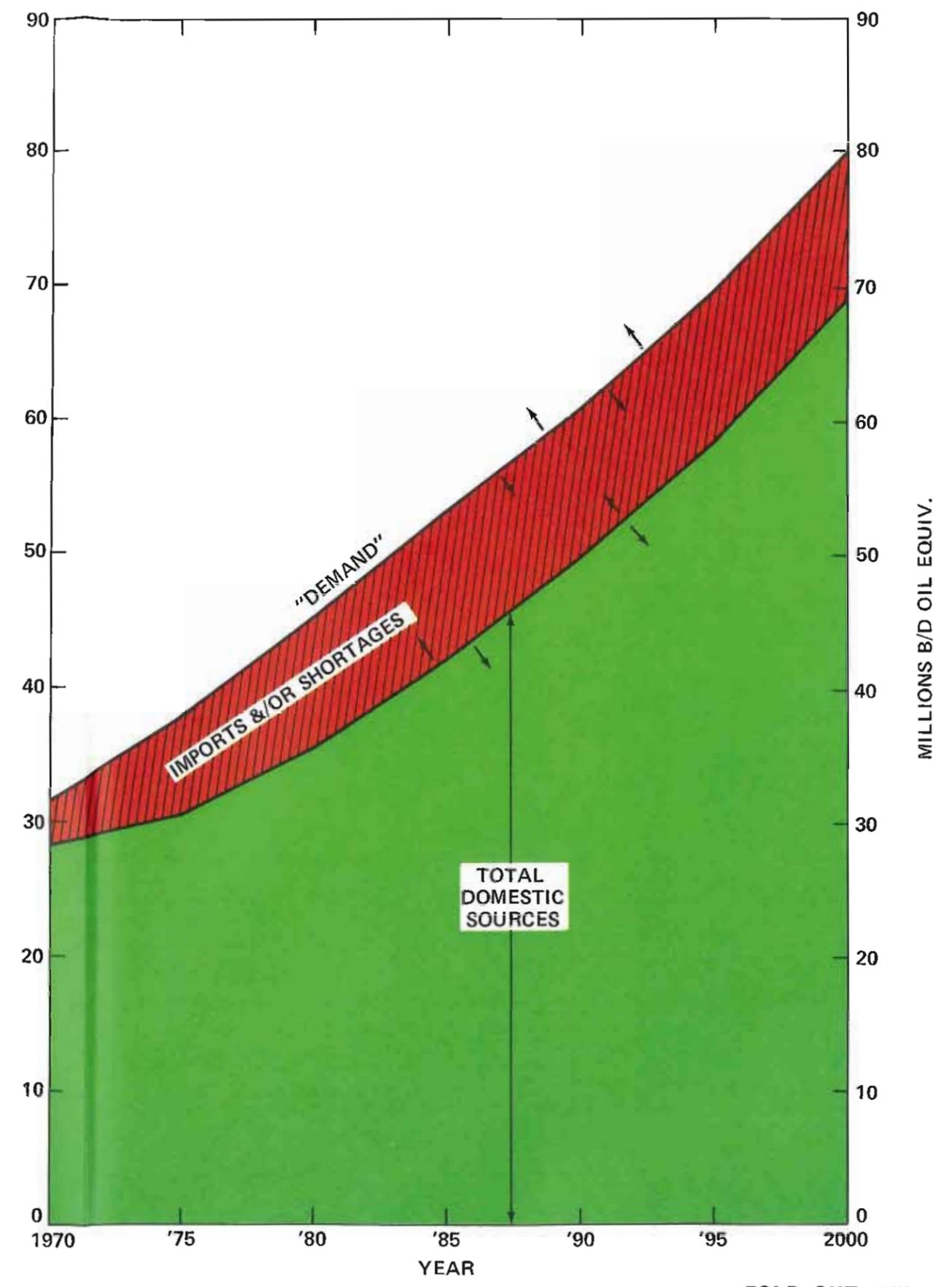
**"SUPPLY/DEMAND"**  
**(1960-1985)**  
**B/D OIL EQUIVALENT vs YEARS**



**L**

FOLD OUT "L"

# "GUIDANCE" REQUIRED



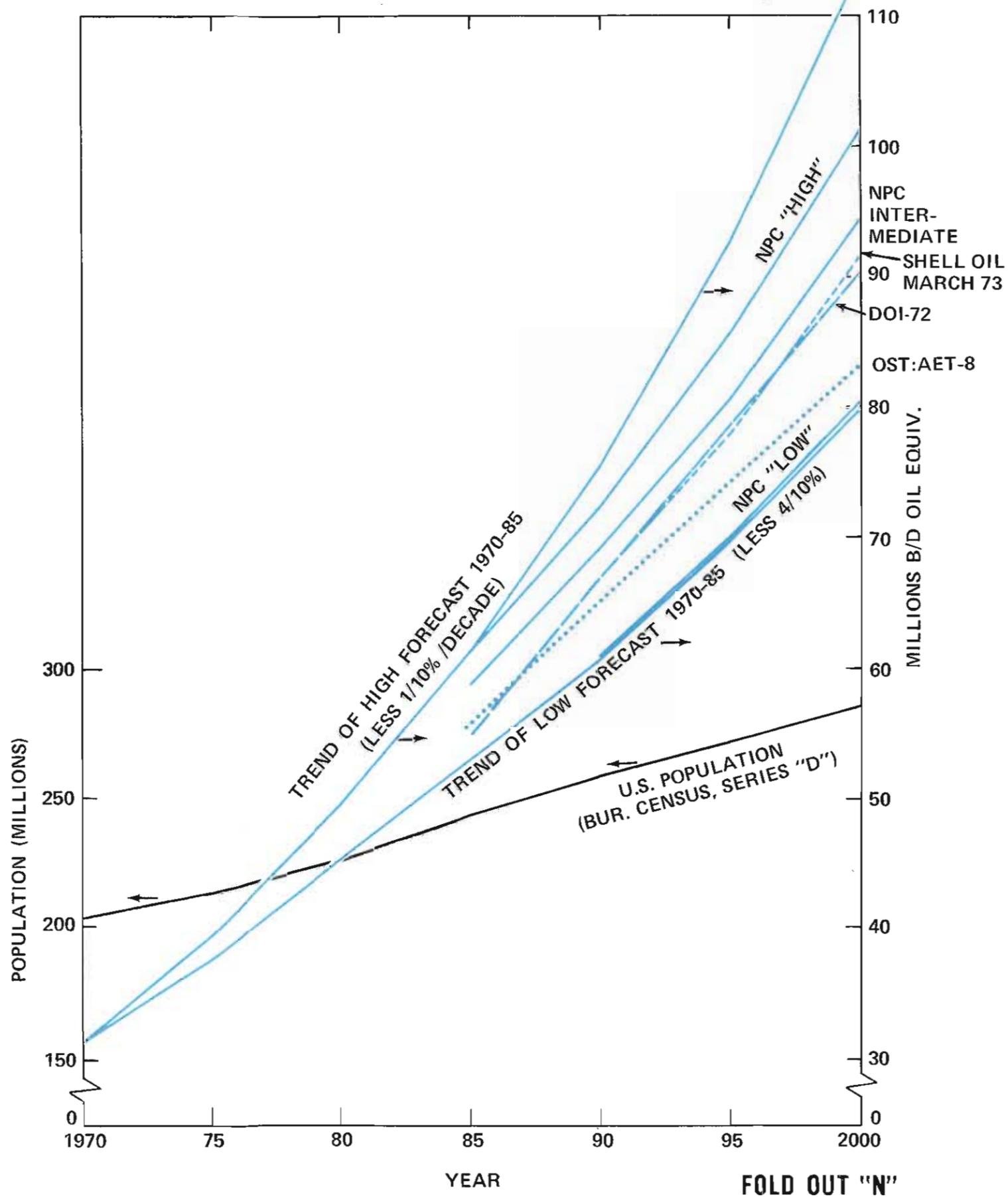
MILLIONS B/D OIL EQUIV.

YEAR

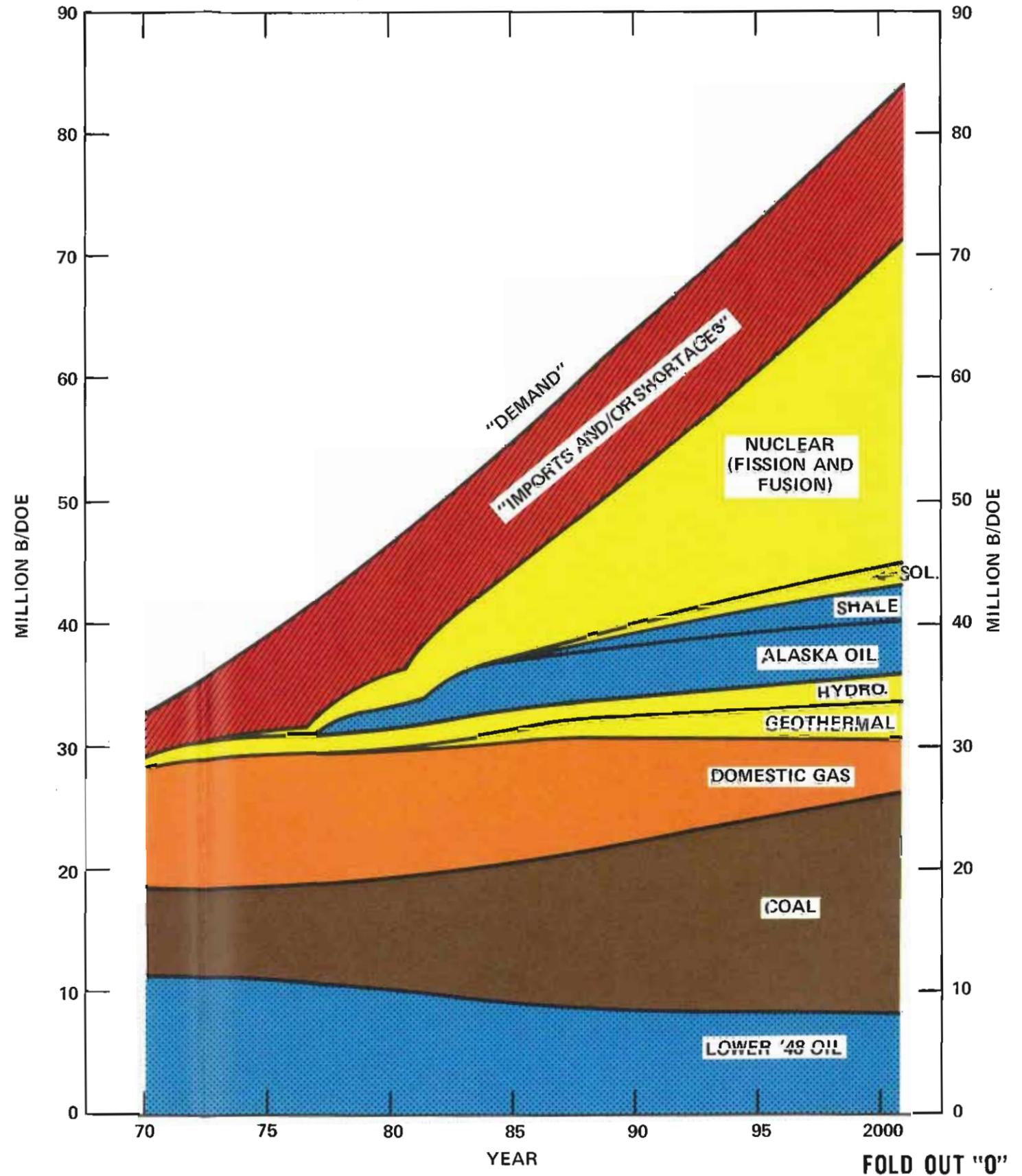
FOLD OUT "M"



# FORECAST OF ENERGY DEMAND TO 2000



**"SUPPLY/DEMAND"**  
**(JCAE "OPTION EXERCISE 7-A" 3-73)**  
**B/D OIL EQUIVALENT vs YEARS**



0

**"SUPPLY/DEMAND"**  
**(1900 - 2050)**  
**B/D OIL EQUIVALENT vs YEARS**

